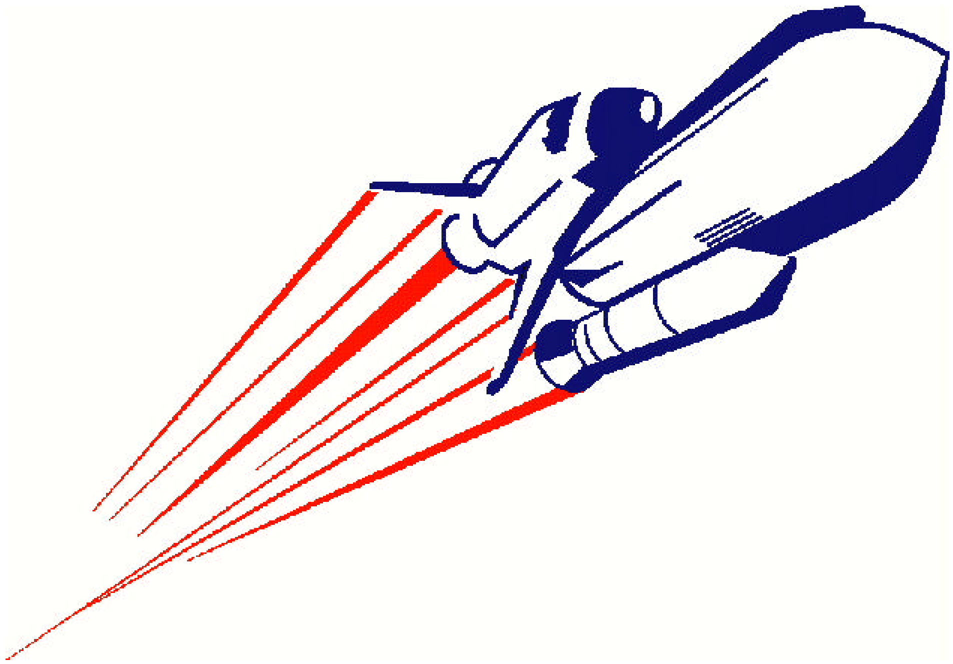

Space Shuttle Program Process Control Standards and Practices

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Background: In 1999 the National Aeronautics and Space Administration (NASA) Space Shuttle Program (SSP) Manager chartered the Process Control Focus Group to coordinate process control activities across the entire SSP. This team is lead by NASA and has representatives from each of the prime contractors and each NASA Center. The team developed the Process Control Management Plan (NSTS 37358), which contains the minimum standards for process control.

Purpose: The purpose of this document is to describe the process control standards and provide *examples* of practices that are currently being utilized. The practices contained in this document are effective for that organization and may require tailoring to meet another organizations specific needs. This document is not all inclusive, but is an aid in the development of process control tools and methodologies.

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Process Control Standards

Standard 1: *Detect and eliminate process variability and uncoordinated changes.*

- Apply statistical techniques to processes that reflect the "health" of the process
- Employ methods to identify and capture results of a process for consistency and immediately detect any "outliers" that would require a cause analysis
- Analyze data for trends to determine capability of a process and ultimately tighten the variability requirements
- Implement methods for early detection of changes in materials, parts, or assemblies

Standard 2: *Eliminate creep through process controls and audits.*

- Periodically examine processes to verify that work authorizing documents clearly and accurately depict the steps necessary to perform the process to meet the established requirements
- Verify that practitioners are performing the work steps as documented
- Provide opportunities to analyze the process for possible enhancements and improvements
- Develop systems where practitioners and engineers can collaborate to ensure that processes are being performed efficiently and effectively

Standard 3: *Understand and reduce process risks.*

- Define risk
- Implement training program on risk management methodology and tools to analyze risks and options to mitigate the risk
- Provide clear risk management responsibilities to management and employees
- Ensure appropriate communication and integration of risk management activities, both horizontally and vertically
- Understand potential risk when a change is implemented
- Develop a system to identify risk, likelihood of occurrence, and the consequence of occurrence
- Implement a system to classify, rank, and assess risks
- Track risks from identification to disposition
- Identify severity level and process to mitigate the risk
- Document risk assessments (quantitative, qualitative)
- Maintain an auditable and measurable system (identify, review, and disposition)
- Ensure risk is a consideration in decision processes and in day-to-day planning and decision-making activities

Standard 4: *Identify key design and manufacturing characteristics and share lessons learned relating to processes.*

- Create informational fact sheets describing the function and criticality of parts being produced
- Maintain a formal requirements flow-down system to convey product drawing requirements to the manufacturer
- Define control and recording parameters for critical part characteristics and processes
- Establish joint contractor/manufacturer pre-production reviews to assess critical hardware production readiness and previous lessons learned
- Establish focal points with technical resources to support manufacturer prior to and during fabrication

Standard 5: *Be personally accountable. Perform to written procedures.*

- Define and document policies that define how stamps and signatures are used
- Create a written policy to address violations
- Train all employees in the importance of personal warranty
- Provide internal controls for stamps/documentation
- Create a company culture which promotes/rewards/recognizes personal accountability
- Promote personal warranty at the subcontractor level, as appropriate

Standard 6: *Promote process control awareness. Understand and report changes.*

- Establish mechanism to communicate with employees and suppliers on the importance of process control and following established policies/procedures
- Foster an environment and culture of questioning and being aware when something appears different or doesn't look right
- Promote the individuals' responsibility and accountability for ensuring the product meets all requirements as documented
- Document process for reporting changes to processes, materials, methods, etc. to the appropriate individuals for analysis and potential impacts to the hardware/software
- Communicate where the individual product is utilized and how all components must work together to ensure success

Standard 7: *Identify and evaluate changes to equipment and environment.*

- Identify the baseline and manage and control any changes to that baseline
- Analyze changes for potential impacts to risk, safety, etc.
- Ensure changes are coordinated, reviewed, and approved by authorized individuals
- Maintain documentation of changes

Standard 8: *Capture and maintain process knowledge and skills.*

- Identify and baseline critical knowledge and skills that are important to the business
- Implement a process for maintaining the baseline
- Identify knowledge and skill gaps and have a plan to address the gaps
- Create company policies and procedures to manage knowledge and skills
- Establish methods for the effective transfer of critical knowledge and skills to appropriate associates (e.g., instructor-led training, mentoring, job shadowing, on-the-job training)
- Deliver refresher training for applicable knowledge and skills
- Employ other methods as necessary to maintain associate process capability (e.g., job rotation)
- Consider lack of knowledge and skills when determining causes of escapes and nonconformances

Standard 1

Practice: Statistical Process Control
Prime Contractor: ATK Thiokol Propulsion
Location: Brigham City, Utah
Point of Contact: Glen Curtis
Phone Number: 435-863-6954
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Overview: Statistical process control (SPC) uses statistical rules to understand the variation of processes. Materials, processes, and results are tracked by traditional SPC and also with a hardware perspective.

Organizations initiate, manage, and document SPC projects to meet business needs. Process owners and component team leadership responsible for that aspect of the product then identify parameters that might give insight to product variability. Parameters are designated, family limits are set, and the information is incorporated in the appropriate shop planning documents. A violation of the family limits causes the operation to stop while process owners evaluate what has changed and what impact that violation might have on the resulting hardware.

Unique designations are used for different types of processes and operations. Process Control Variables (PCV) track selected manufacturing processes and material characteristics. Hardware Variation Notice (HVN) variables flag violations of family limits during operations at KSC. Post-fire Control Variables (PFCV) identify trends on post-fired hardware and correlate to preflight conditions.

Traditional SPC identifies in real time a process that needs attention (out of control, population shift, adverse trend, special cause) to improve quality and reduce cost. Expanded SPC (hardware perspective) identifies in real time and assesses flight hardware that may be different from the norm to assure continued flight safety. The system addresses unique hardware or process concerns such as limited production runs, parameters that have not experienced the full range of engineering specification limits, and a person-rated system.

Incorporating variable limits into planning ensures a closed loop, real time review. Violation of an established limit indicts hardware, stops the production line, and is documented on a discrepancy report. Limit violations are dispositioned by a manufacturing engineer and quality engineer as a minimum. If the violation is not understood, or risk is high, the violation is elevated to the necessary level to understand the condition or mitigate/accept the risk.

Conclusion: SPC provides real-time collection and assessment of significant parameters and provides insight into quality of processes (repeatability) and quality of products (reduced variation).

Standard 1

Practice: Fingerprinting of Incoming Material
Prime Contractor: Lockheed Martin Space Systems Co., Michoud Operations
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Phone Number: 504-257-1849 or 257-1756
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Overview: Materials used in the Space Shuttle are critical to successful mission performance. Subtle changes in materials can have an adverse – even a catastrophic consequence. Changes in material supplier processes or procedures or minor changes in raw chemicals used in formulating materials can cause adverse drift in the material end use properties and material capabilities.

Material fingerprinting, using state-of-the-art chemical analysis techniques, is an excellent way to determine changes in material processes and ingredients. Each lot of material critical to flight is chemically analyzed to establish a chemical fingerprint. This fingerprint is then stored in a database for use in accepting future lots of material. When a new lot of material arrives at the customer's facility, technical laboratories perform tests and characterize (fingerprint) the material to assure that the end product has been manufactured to engineering specification and ingredients used to formulate the material are the same as previously received materials.

Statistical evaluation of the test results is performed and reviewed by Procurement Quality Control. The data is compared with previous lots of material and if any parameter, even though within the engineering specification, is **outside the family** (outside the parameters observed on previous lots), the material is not approved for use, and further evaluation is conducted.

A Material Data Analysis Team (MDAT) consisting of Technical Operations, Production Operations, and Product Assurance reviews the data and evaluates the affects of the parameters that are outside the family.

Only upon acceptance by the MDAT team is the material accepted for use in production. If the MDAT team rejects the material, though the material is within the engineering specification, the material is dispositioned unacceptable for flight usage and the material is scrapped. This preventive measure has and can prevent costly rework.

Additional Information: A relationship/partnership between the customer and the manufacturer of materials is developed. The customer shares the database and the trend charts with the supplier. This produces a partnership that helps the supplier know if their process is within family or adversely drifting. Both the customer and supplier can see any adverse trends and the supplier can take immediate corrective action. These fingerprinting tests and related statistical process control (SPC) charting, as well as communication with the supplier have proven to be an effective tool in reducing anomalies in materials.

Conclusion: Fingerprinting provides greater control of materials by establishing a standard of key material characteristics to which comparisons of incoming materials can be made. The material fingerprint is used to monitor supplier process drift and raw ingredient changes.

Standard 2

Practice: Product/Process Integrity Assessments
Prime Contractor: United Space Alliance
Location: Cape Canaveral, Florida
Point of Contact: Tammi J. Belt
Phone Number: 321-867-8326
E-mail: Tammi.J.Belt@usa-spaceops.com

Overview: Product/Process Integrity Assessments are performed to ensure that the intent of the design is properly documented on the Work Authorizing Document, Manufacturing Planning, and Specifications. The assessment team consists of an Independent Team Leader (qualified Lead Auditor), Design Engineer, Test Engineer, Quality Control, Technician, and Technical Associate/Operator as a minimum. The team performs and/or processes the hardware scrutinizing all applicable documents to verify that the planning and instructions are clear, correct, easily executed, and can be verified.

Any observations are properly documented and recommendations are made and agreed to by the entire team. The observations are categorized based on criticality as follows:
Category 1: Hardware requires re-inspection, rework, <u>and has</u> possible fleet problem.
Category 2: Changes required prior to the next application of the task/operation. 2A - Work performed satisfies specification/drawing requirements but the planning is in error or silent.
2B - Work performed as planned but violates specification/drawing requirements <u>and must be</u> processed as a Material Review (MR)/waiver.
2C - Best method required to performed the task or the method requires a specific practice (i.e. mandatory sequence, safety concern, personnel qualification and/or training, mandatory procedure).
2D - Individual cannot <u>warrant</u> the task was completed exactly as planned.
Category 3: Minor documentation error and/or all other changes.

Conclusion: A PPIA identifies any errors in the planning and/or requirements to be corrected to prevent recurrence.

Standard 2

Practice: NASA Engineering & Quality Audit
Contractor: United Space Alliance
Location: Cape Canaveral, Florida
Point of Contact: Tammi Belt
Phone Number: 321-867-8326
E-mail: Tammi.J.Belt@usa-spaceops.com

Overview: The objective of a NASA Engineering & Quality Audit (NEQA) is to assure that all manufacturing and assembly operations will provide safe and reliable hardware. The audit verifies that the planning documents correctly reflect the specifications and drawing requirements and proper levels of control are in place to establish planning requirements. It also verifies that the appropriate levels of authority are involved in the review and approval of planning; training and certification are adequate to support the required tasks; planning and instructions are clear, correct, and easily executed and can be verified; conformance to contract requirements through traceability of the product to engineering specifications and drawings; and that inspection stamps provide warranty of satisfactory completion and verification of operations.

Similar to the Process Product Integrity Audit, the NEQA has two phases. Phase I is an internal audit by the contractor with a focus on the hardware. A team of six to eight practitioners conducts the assessment. The focus of the Phase I is planning and documentation; training and certification of operators and inspectors; compliance to instructions; and stamp warranty. Findings are documented into the following categories:

Category 1 – Safety of Flight
- Must be evaluated and <u>cleared before next launch</u>
- Must be corrected immediately

Category 2 – Incorrect Documentation, Best Practices, and Stamp Warranty
- Not a Flight Safety Issue
- Must be <u>corrected prior to next usage</u>

Category 2 – (sub-categories)
- 2A – Planning incorrect (specifications/drawings OK)
- 2B – Drawings/Specifications incorrect (planning OK)
- 2C – Best method to assure product integrity and process performance. Caution to stay “within family” of experience
- 2D – Others: including assuring Operator/Inspector stamp warranty

Category 3 – Editorial and Better Practices
- Correct when <u>convenient</u> or next opportunity

Phase II is a team of NASA and contractor system personnel and cannot be the same people as Phase I. There is no restriction to the size of the team and the members are personnel with the proper skills related to the scope. Customer participation is mandatory for Phase II. The focus is on planning activities; personnel warranty, certification, etc.; hardware inventory, controls and tooling; and manufacturing and assembly.

Standard 2

Practice: Quality System Audits
Prime Contractor: United Space Alliance
Location: Kennedy Space Center, Florida
Point of Contact: Tammi J. Belt
Phone Number: 321-867-8326
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Overview: Quality System audits are performed at suppliers to ensure that all imposed contractual requirements are being adhered to. The customer visits the suppliers' facility and verifies that the manufacturing and/or special processes continue to be performed per the established baseline. The Quality System audit gives the customer the visibility into the supplier's quality system, procedures, work instructions, and implementation thereof.

If changes to already established processes are deemed necessary, the supplier proceeds through the appropriate configuration control boards and panels and must receive approval from the customer prior to implementation. The strict adherence to this requirement is essential to ensure the hardware and/or process performs as designed.

The Quality System audits also provide the auditor insight into the suppliers' manufacturing processes and metrics that are utilized to manage those processes. Statistical Process Control charts are typically located throughout the facility in addition to other performance measures. Many organizations are striving for Six Sigma and have established tighter controls on their processes in an effort to reduce process drift.

Standard 2

Practice: Quality Control System Survey (Bottoms-Up)
Prime Contractor: Lockheed Martin Space Systems Co., Michoud Operations
Location: New Orleans, Louisiana
Point of Contact: Shy Parikh or Ken Bornstedt
Phone Number: 504-257-1849 or 257-3642
E-mail: Shailesh.A.Parikh@maf.nasa.gov or Kenneth.A.Bornstedt@maf.nasa.gov

Overview: Product Assurance system surveys are performed at suppliers to assure that materials and services meet the safety, reliability, and quality standards required by the customer. The survey normally consists of reviewing the supplier's Product Assurance procedures and then obtaining verification of implementation.

A more thorough method of conducting a survey is dubbed a "Bottoms-Up" survey. The philosophy is to start the survey at the end or start of the product line, the shipping or the receiving area. Procedures, etc. are reviewed at the end of the survey. The survey technique is outlined in a written detailed survey plan, which is given to the supplier prior to the survey and also explained during the survey in-briefing.

The surveyor starts from the shipping or receiving area and works backward/forward through the manufacturing process to the actual procurement of the raw material or shipment of the flight hardware. An important aspect of the survey is that the surveyor interfaces with the actual practitioners, who perform the work. Documents such as procedures, specifications, work instructions and tools/inspection equipment utilized would be noted for later reference. All elements of the Product Assurance system are reviewed during this process, i.e. Procurement, Fabrication, Testing, Nonconformance, Metrology, Stamp Control, etc. Some elements may be reviewed towards the end of the survey using data collected during the "Bottoms-Up" process.

Additional Information: Not only does the "Bottoms-Up" survey technique provide for a more thorough survey, supplier management and practitioners appear to enjoy the survey activity. Customer representatives (NASA) who participated in supplier surveys were very impressed with the depth of survey activity.

Standard 3

Practice: Process Risk Matrix
Prime Contractor: Boeing Rocketdyne
Location: Canoga Park, California
Point of Contact: Bruce Chandler
Phone Number: 818-586-1531
E-mail: bruce.r.chandler-jr@boeing.com

Overview: The Process Risk Matrix provides an assessment of hardware fabrication and utilization risks by identifying, understanding, and assessing important process features. Generation of the Process Risk Matrix is the responsibility of the Quality Engineering function. This Matrix characterizes specific processes and assigns one of two risk levels to process specifications based on input from the specification owners and resident process experts. This Risk Matrix ranking is used in the Build-to-Package (BTP) process to assess the level of BTP criticality for an associated piece of hardware. Lessons Learned are considered in the generation and maintenance of the Process Risk Matrix.

Standard 3

Practice: Characteristic Risk Analysis (RA) (Advanced Quality System Risk Analysis)
Prime Contractor: Boeing Rocketdyne
Location: Canoga Park, California
Point of Contact: Bruce Chandler
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Overview: The Characteristic Risk Analysis (RA) is part of the Build-to-Package (BTP). The BTP provides a comprehensive product requirements definition to procure hardware. A Characteristic Risk Analysis is a method for assessing the risk associated with the variation of individual product characteristics from their target values. Generation of the RA is the Integrated Product Team's (IPT) responsibility. This effort is coordinated by the IPT's Quality Engineer and is performed in a team environment with participation from affected disciplines and the supplier.

- Characteristic Risk Analysis (RA) – A method for assessing the risk associated with the variation of individual product characteristics from their target values. This assessment includes identification of potential causes and effects of variation; an estimation of risk associated with (1) the probability of nonconformance (occurrence), (2) effects of variation (severity), and (3) the ability to detect nonconformances (detectability). In addition, appropriate management methods (i.e. SPC, first article, 100% inspection, etc), and characteristic classifications are listed.

Additional Information: All FMEA/CIL defined inspections and tests are included in the Characteristic RA process.

Standard 3

Practice: Process Failure Modes Effects Analysis (PFMEA)
Prime Contractor: ATK Thiokol Propulsion
Location: Brigham City, Utah
Point of Contact: Blaine A. Frandsen
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E-mail: blaine.frandsen@atk.com

Overview: A PFMEA is an analytical technique, which identifies potential process failure modes, assesses the potential cause and effects of the failure, identifies the potential manufacturing or assembly process causes, and identifies significant process variables to focus controls for prevention or detection of the failure conditions. It utilizes occurrence and detection probability in conjunction with severity criteria to develop a Risk Priority Number (RPN) for prioritization of corrective action considerations.

A PFMEA is a structured methodology for an engineer to identify potential failure modes for a new or changed manufacturing process. This systematic approach parallels and formalizes the mental discipline that an engineer normally uses to develop processing requirements. It can also assist in developing new machines or equipment. If a process has been on-going for some time, a PFMEA can help find problem areas. A PFMEA is also performed when any process is being changed. By performing a PFMEA for a process change, it will help identify if the change will add any new failure modes or causes.

Benefits:

- Technique for identifying and prioritizing potential failures in a process or product
- Method for measuring relative merit of process changes
- Uses a quantitative and qualitative approach
- Identifies processes which mitigate identified process risk
- Team approach using structured brainstorming tools

Conclusion: PFMEA mitigates risk by identifying and controlling potential failures in a process/product for a proposed process change or a new manufacturing process prior to implementation.

Standard 4

Practice: Build-to-Package
Prime Contractor: Boeing Rocketdyne
Location: Canoga Park, California
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Overview: The Build-to-Package (BTP) concept provides a comprehensive product requirements definition to procure hardware. A BTP consists of data elements whose objectives are to clearly define and flow requirements to suppliers and to assure customer(s) needs are met throughout intended product life. This includes performing an assessment of hardware fabrication and utilization risks; incorporating existing lessons learned, identifying, understanding, and controlling important processes and features, and assuring implementation of mandatory inspections. Generation of the BTP is the Integrated Product Team's (IPT) responsibility. This effort is coordinated by the IPT's Quality Engineer and is performed in a team environment with participation from affected disciplines and the supplier. Important elements of the BTP process include:

- <u>Characteristic Risk Analysis (RA)</u> – A method for assessing the risk associated with the variation of individual product characteristics from their target values. This assessment includes identification of potential causes and effects of variation; an estimation of risk associated with (1) the probability of nonconformance (occurrence), (2) effects of variation (severity), and (3) the ability to detect nonconformances (detectability). In addition, appropriate management methods (i.e. SPC, first article, 100% inspection, etc), and characteristic classifications are listed. All FMEA/CIL defined inspections and tests are included in the Characteristic RA process.

- <u>Characteristic Accountability Worksheet (CAW)</u> – The CAW is used to document requirements, process controls, and verification methods needed to mitigate risks associated with the characteristics identified during the Characteristic Risk Analysis process. Completion of the CAW requires input from both customer and the supplier, and approval by the customer.

- <u>Procured Product Acceptance Requirements (PPAR)</u> – The PPAR specifies source and receiving inspections, summarizes requirements, lists applicable drawings/specifications, and identifies special instructions.

Additional Information: There are three hardware risk categories based on hardware criticality and other considerations. Category 1 hardware requires a PPIA, RA, CAW, and PPAR. Category 2 requires RA, CAW, and PPAR. Category 3 requires a PPAR.

Standard 4

Practice: Characteristics Accountability Worksheet (CAW)
Prime Contractor: Boeing Rocketdyne
Location: Canoga Park, California
Point of Contact: Bruce Chandler
Phone Number: 818-586-1531
E-mail: bruce.r.chandler-jr@boeing.com

Overview: The Characteristics Accountability Worksheet (CAW) is part of the Build-to-Package (BTP). The BTP provides a comprehensive product requirements definition to procure hardware. The CAW identifies critical and significant characteristics and their associated control methods. Generation of the CAW as part of the BTP is the Integrated Product Team's (IPT) responsibility. This effort is coordinated by the IPT's Quality Engineer and is performed in a team environment with participation from affected disciplines and the supplier.

- Characteristic Accountability Worksheet (CAW) – The CAW is used to document requirements, process controls, and verification methods needed to mitigate risks associated with the characteristics identified during the Characteristic Risk Analysis process. Completion of the CAW requires input from both the customer and supplier, and approval by the customer.

Additional Information: There are three hardware risk categories based on hardware criticality and other considerations. Category 1 and 2 hardware requires a CAW as part of the BTP.

Standard 4

Practice: Product Brochures/Fact Sheets
Prime Contractor: ATK Thiokol Propulsion
Location: Brigham City, Utah
Point of Contact: Scott Eden
Phone Number: 435-863-6322
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Overview: Product brochures are developed by a customer for each of his suppliers as a tool to communicate where the supplier's products are used on the Space Shuttle and the importance of these items to the success of every Space Shuttle flight.

A brochure contains:

- A picture or drawing of where the supplier's product is used on the Space Shuttle vehicle
- A narrative description of the importance of the product to mission success
- A Safety First message
- Some facts about recent Shuttle missions and their importance to the nation
- Some internet web sites where people can find more information on the space program

Brochures are popular with suppliers for the following reasons:

- Employees share them with family and friends as an expression of pride for working on the Space Shuttle Program
- Suppliers use them as an advertising tool to describe their involvement in the highly reliable and successful Space Shuttle Program
- The fact sheet side of the brochure can be attached to shop planning documents as a reminder that the product being manufactured will be used on the Space Shuttle
- The fact sheet side can also be enlarged to poster size for display in the supplier facilities as a motivational tool

Conclusion: Product brochures are a low cost, highly effective way to communicate with people who make products for the Spare Shuttle. People can see exactly where the product they make is used and how important it is to each mission. A brochure communicates an important safety message, and provides information where employees can obtain additional information about the U. S. space program the Space Shuttle.

Standard 4

Practice: Process Baselines
Prime Contractor: ATK Thiokol Propulsion
Location: Brigham City, Utah
Point of Contact: Hilda Poole
Phone Number: 435-863-5893
E-mail: hilda.poole@atk.com

Overview: Configuration management direction, guidance and surveillance are provided to suppliers by imposing configuration management standards through purchase order documents. The degree to which configuration management is invoked is tailored to each supplier so that only those controls deemed necessary are imposed.

Program teams, directed by the Configuration Management Office, determine the need to baseline a supplier's process (i.e. formally control process documentation) based on one or more of the following criteria: criticality of material/component, complexity of the process, sensitivity of the process, ability to control the process and inspectability of the material/component.

Process baseline documents to be controlled are determined and may consist of: engineering documents, manufacturing standards, quality inspection plans, sub-tier supplier documents, etc. Once these documents have been baselined (approved by both the supplier and the customer), any changes must be reported to and approved by the customer prior to implementation. A formal change control system is required where changes are classified with varying degrees of configuration control being applied depending on the classification of the change. Program teams, as well as applicable change control boards, approve changes. Coordination of all change activities is communicated through Procurement.

All materials/components with baselined processes are identified in a Qualified Products List (QPL) to assure they are purchased from baselined suppliers. The QPL is reviewed yearly for manufacturer accuracy and to determine if the manufacturing of each item has taken place within 12 months, ensuring all engineering and processing requirements are met. In addition, each baselined supplier receives on-site, periodic audits to insure compliance with configuration management requirements.

Conclusion: This practice provides the customer with insight on supplier processes and changes. It allows the customer the opportunity to review changes, assess risk, and verify acceptability of changes prior to incorporation into flight hardware. It also enhances communication and encourages a closer working relationship with suppliers, heightening process control awareness that is so critical to the Space Shuttle Program.

Standard 5

Practice: Personal Warranty (Stamp & Signature)
Prime Contractor: Boeing Rocketdyne
Location: Canoga Park, California
Point of Contact: Alan Kay
Phone Number: 818-586-7566
E-mail: alan.r.kay@boeing.com

Overview: The objective of a Personal Warranty program is to establish personal accountability. Personal Warranty is essential to the integrity and mission success of space flight hardware. Warranty is the application of stamps or signatures ensuring compliance with governing documents and that all required work has been performed to the applicable standards. Warranty is a personal responsibility that involves ethics, integrity, and provides customer confidence.

Training Tools: Computer-based training tools (CD-ROM) have been developed to provide Personal Warranty awareness to employees and suppliers. Warranty issues are presented through case studies and interactive participation. Successful completion of the training assures employees understand warranty and the implications of non-compliance. A warranty violation occurs when an individual signs or stamps a document signifying compliance when the instructions were, in fact, not followed. Violations of this policy are investigated and addressed by management and Employee/Labor Relations. Annual “Attention to Detail” meetings are also conducted with employees, suppliers, and the customer to re-emphasize the importance of warranty and workmanship.

Standard 6

Practice: Space Flight Awareness Program
Prime Contractor: United Space Alliance
Location: Cape Canaveral, Florida
Point of Contact: Tammi J. Belt
Phone Number: 321-867-8326
E-mail: Tammi.J.Belt@usa-spaceops.com

Overview: The Space Flight Awareness (SFA) Program is a NASA managed motivational program with invited representation from the Office of Space Flight Field Centers, other NASA Field Centers, and contractors having major responsibilities for human space flight mission success. This Program meets the NASA requirements for contractors to participate in a NASA motivational program.

The purpose of the SFA Program is to ensure that each and every employee involved in human space flight is aware of the importance of their role in promoting astronaut safety and mission success in the critical, challenging task of flying humans in the hostile environment of space by communicating and educating the Government/Industry workforce about human space flight.

Space Shuttle Program Prime Contractors are a member of the SFA Panel. These Panel Members are responsible for the SFA Program at their respective major contract element location and responsible sites. They are also responsible for providing active support and guidance to their major and critical subcontractors to ensure an effective SFA Program at their major and critical subcontractor's locations. They are the point of contact for SFA activities (e.g., astronaut visits, Silver Snoopy presentations, Honoree selections, SFA Team Awards and mission decal/poster distribution) and events at their location and for their subcontractors/critical suppliers.

Standard 6

Practice: Motivational Visits to Suppliers
Prime Contractor: United Space Alliance
Location: Cape Canaveral, Florida
Point of Contact: Tammi J. Belt
Phone Number: 321-867-8326
E-mail: Tammi.J.Belt@usa-spaceops.com

Overview: Supplier visits are an invaluable tool in improving communication, sharing lessons learned, best practices, and discussing issues and concerns. There are various types of visits with differing desired outcomes, but the motivational visit provides the best results and is most accepted by the supplier.

The motivational visit is typically conducted by members of executive management and is supported by a representative from Material and Space Flight Awareness. In addition, many of the visits have an astronaut in attendance, who walks through the supplier's facility and meets with the employees. This one-on-one contact with the employees has a tremendous impact and is greatly appreciated. These visits are an opportunity to share with the supplier how important their continued support of the Space Shuttle Program is and where their hardware is located on the vehicle.

The targeted audience on these visits is the employees, however in many instances it is the management and executive management of the supplier. It is during these meetings that open dialog concerning lessons learned takes place. Meeting face-to-face with suppliers enhances the customer/supplier relationship and provides the opportunity to discuss expectations, and reinforce process control.

Standard 6

Practice: Symposiums
Prime Contractor: United Space Alliance
Location: Cape Canaveral, Florida
Point of Contact: Tammi J. Belt
Phone Number: 321-867-8326
E-mail: Tammi.J.Belt@usa-spaceops.com

Overview: The benefits of hosting a supplier symposium/conference are numerous. It is a great method to ensure that all of your suppliers hear the same message at the same time and provides them the opportunity to voice their concerns and participate in some dialog with other suppliers in the industry. The atmosphere of a supplier symposium/conference is about sharing and learning from one another without attention being focused on a specific supplier. It enables contacts to be made and fosters closer working relationships between the customer and supplier.

Standard 6

Practice: Videos/Posters
Prime Contractor: United Space Alliance
Location: Cape Canaveral, Florida
Point of Contact: Tammi J. Belt
Phone Number: 321-867-8326
E-mail: Tammi.J.Belt@usa-spaceops.com

Overview: The task of increasing awareness on Process Control can be overwhelming. There are numerous methods and tools to chose from and one that is believed to be effective is the video. People learn differently, some are visual while others learn by hearing or reading. The use of the video ensures that everyone hears the same message and it may be viewed more than once to reinforce the message. Typically a video should be between 10 – 15 minutes in length, videos longer in duration tend to lose the audience. The video should target a particular topic or message that you are trying to convey and should be entertaining as well.

In addition, videos are an excellent tool to share with suppliers. They can be previewed at a supplier conference/symposium and then be provided to those who request them and/or be distributed to your supplier base automatically. As technology continues to advance, additional tools will become available such as the DVD. Along with videos, posters can be printed that relate to the video and be put on display in the work areas, which will serve as a constant reminder of the message from the video. To increase awareness and change the culture or belief on a particular topic the message needs to be in front of people all the time so that it becomes second nature. Videos and posters are an excellent tool to do that.

Standard 7

Practice: Product Protection Analysis
Prime Contractor: Hamilton Sundstrand Space Systems International
Location: Windsor Locks, Connecticut
Point of Contact: Thomas Crouss
Phone Number: 860-654-6370
E-mail: Thomas.Crouss@hs.utc.com

Overview: The Product Protection Analysis (PPA) is a review process used to identify potential hazards to flight hardware that can be encountered during testing. These hazards can be caused by the test rig, facility, tooling and/or test environment. Once the PPA is completed and hazards are identified, changes are incorporated to eliminate these hazards.

A PPA is required for all items tested with protoflight or acceptance test procedures and meets one or more of the following criteria: *a) electrical products, b) products exceeding a sale value limit set by management, c) products whose operating pressure exceeds 2,200 psi, d) major subcontract products that are tested at the customer's facility, and e) products whose schedule impact is critical to the customer.*

To perform a PPA, the test item is first reviewed by the responsible Test Engineer to determine its level of complexity. For non-complex hardware, a PPA may be performed by a Test Engineer alone. For complex hardware, the Test Engineer forms an interdisciplinary team composed of representatives from Engineering, Operations and the Space Systems Laboratory to perform the PPA.

The Test Engineer or PPA team performs the PPA and identifies a list of hazards to be mitigated. From this list, actions are generated to address all the identified hazards. Corrections are then implemented to mitigate these hazards. Upon completion of all actions, the item can be released to the Space Lab to commence testing.

As a result of performing the PPA, a baseline configuration of the hardware to the rigs, facility, special test equipment and tooling is developed. This baseline is then used to identify any changes that have occurred prior to the next time the hardware is tested. If there have been changes they are assessed for possible risk to hardware damage. Mitigation steps are then implemented and the baseline documentation is updated for future use.

Standard 7

Practice: Configuration Management
Prime Contractor: ATK Thiokol Propulsion
Location: Brigham City, Utah
Point of Contact: Keith H. Foulger
Phone Number: 435-863-5732
E-mail: keith.foulger@atk.com

Overview: Configuration management (CM) is a business process that insures products and processes meet contract requirements. CM is a closed loop, formal set of principles that insures:

- Product and process requirements are identified and documented
- Changes to requirements are properly controlled
- Requirements are accounted for throughout the product and process life cycle
- Reviews and audits are conducted to insure requirements are identified, controlled, and accounted for

Configuration Management II (CM II) as developed by the Institute of Configuration Management (ICM) of Scottsdale, Arizona has been adopted by government agencies, government contractors, and commercial companies around the world as a best business practice. The CM II model uses the following principles to provide a business process infrastructure that insures products and processes meet customer requirements:

- Product requirements are best defined and documented by item hierarchies that provide parent-to-child relationships
- Requirement documents are linked to their items
- Item hierarchies facilitate bill of material development
- Requirements and data are best managed and validated by the primary creator and user of each document
- The change management process is closed loop and provides necessary rigor based upon change technical and business risk
- Low risk changes have a fast track option
- CM II processes support supply chain management, capacity planning, and scheduling

Benefits of Configuration Management II:

- Insures products and processes meet customer requirements
- Develops product and process requirements that are clear, concise, and valid
- Is cost effective since change management rigor is based upon change risk
- Provides requirements traceability throughout the product and process life cycle
- Facilitates continuous improvement

Further information can be obtained on Configuration Management II by contacting the Institute of Configuration Management (ICM) at www.icmhq.com, or by calling 888-816-2644.

Standard 7

Practice: Engineering Source Approval (ESA)
Prime Contractor: Pratt & Whitney
Location: E. Hartford, CT
Point of Contact: Ken Larson
Phone Number: 860-565-3598
E-mail: larsonk@pweh.com

Overview: ESA (Engineering Source Approval) is a system of management, utilizing the IPD (Integrated Product Development) process that designates sources with specialized skills and/or knowledge and then approves their process capabilities to consistently produce and deliver critical parts.

Engineering designates sources when the supplier's rights in design or processing must be maintained or when characteristics vital to the performance or integrity of a part cannot be practically defined. Process control is assured by procurement from a source, which has demonstrated to the satisfaction of an Integrated Product Team, or it's delegate, the ability to produce the necessary part characteristics. Many of these characteristics are dependent upon the manufacturing process, i.e. forging, casting, coatings, manufacturing excellence, etc.

ESA is invoked on product requirements documents via drawing notes and/or material and process specifications. Implementation of each ESA process is initiated by designation of suppliers with specialized skills and knowledge. In conjunction with the supplier process engineers, the Materials & Processes Engineering (MPE) group approves processes (technical capability) and documents "frozen" manufacturing process sheets. MPE review and approval of all subsequent process changes and variations to the "frozen" process is assured via the ESA system.

It is important to understand that the customer does not tell a supplier how to manufacture a part. The engineering requirements are incorporated on the drawing but the know-how, sequencing and detailed processes that could be used to manufacturer the part are not specified. Because many of the characteristics resulting from a given method of manufacture cannot be practically inspected, the processes producing the characteristic must be evaluated and controlled to assure metallurgical integrity and consistency of the characteristics on the finished product. After initial process approval, the process must be controlled and monitored. The characterization and establishment of the initial process may, and often does, use many of the tools used to establish certified processes. Certifying vital characteristics, such as residual stresses and metallurgical integrity requires innovative approaches because destructive evaluations are the only tools currently available to ensure control of these characteristics. The ESA system relies extensively on metallurgical evaluations for establishing controlled processes and placing appropriate limits on sensitive parameters to assure process consistency. Another vital tool used by the ESA system is process witnessing and demonstrations of critical processes performed in the presence of ESA engineers, who understand the capabilities and sensitivities of the materials and processes required to produce a part meeting all engineering requirements and "design intent". Many critical processes and parts require the skill and expertise of trained operators to ensure a consistent product and the operator's techniques cannot always be reduced to something that is easily measured or monitored. The ESA System, however, provides a vehicle that permits monitoring of suppliers with these critical skills and ensures the exchange of technical information to maintain these necessary skills.

Conclusion: ESA imposes the engineering controls to assure repeatable results for critical processes that cannot otherwise be defined and require close monitoring.

Standard 7

Practice: Manufacturing Material Control (MMR System)
Prime Contractor: ATK Thiokol Propulsion
Location: Brigham City, Utah
Point of Contact: Keith Foulger
Phone Number: 435-863-5732
E-mail: keith.foulger@atk.com

Overview: Materials used in the manufacturing process, which do not become a part of the end item, but contact the end-item have the potential to adversely affect the end item if they are not controlled. For example, an abrasive pad contaminated with silicone used to clean a bonding surface result in a bond that would fail.

Manufacturing materials are evaluated by a cross functional team composed of representatives from each manufacturing area, Procurement Quality, Safety, Supply Management, Material and Process Engineering, R&D Lab, Process Control Lab, and Contamination Control. The team determines appropriate material, inspection, procurement, and control level requirements based on criticality and usage.

Manufacturing materials must be controlled by a Federal, Military, or Industrial specification (e.g. reagent grade chemicals) and/or require in-house testing or inspection to ensure fabrication controls. These materials are under configuration management change control requirements so that material changes are reviewed by applicable review boards.

The requirements for each material are identified and maintained on a Manufacturing Material Requirements (MMR) card. These requirements include:

> Item description, stock number, material requirements, manufacturer name and part number, inspection code, receiving inspection requirements, hazard code, restricted use code, supplier requirements, in-house requirements, originating organization, usage application, and manufacturing planning change number reference.

Manufacturing material supplier changes are evaluated for impact to the material and a Quality Watch notice is issued to alert users of the material so they can assess the impact for their application. Changes are then processed to revise the MMR card if appropriate.

Manufacturing materials are called out in manufacturing planning, based on approved MMR card requirements.

This system provides a control system for all manufacturing support materials that may come in contact with the end item and insures that manufacturing materials are properly controlled to preclude adverse impact to the end item.

Standard 7

Practice: No Change Policy
Prime Contractor: Lockheed Martin Space Systems Co., Michoud Operations
Location: New Orleans, Louisiana
Point of Contact: Shy Parikh or Ken Bornstedt
Phone Number: 504-257-1849 or 257-3642
E-Mail: Shailesh.A.Parikh@maf.nasa.gov or Kenneth.A.Bornstedt@maf.nasa.gov

Overview: Subtle changes in processing or fabricating flight hardware can have an adverse affect. To mitigate this, a "no change policy" clause is levied on all subcontractors through the subcontract purchase agreement. This contract requirement requires the supplier to notify the customer of any change; including personnel, equipment, material, tooling, etc. subsequent to start of production. The supplier is required to obtain customer approval in writing to any deviation and/or exception to the procurement specification. The supplier cannot implement changes unless authorized by the customer in writing.

In addition, fabrication controls were implemented through contract requirements that require all suppliers of flight hardware to prepare charts indicating the flow of articles and materials from receiving through fabrication operations, test and/or delivery; and showing the location of inspection and test stations or points in relation to the flow of articles and materials. Control documents, such as drawings, specifications and processes, shall be referenced and associated with each inspection and test station or point. These charts require approval by the customer prior to the start of fabrication.

Additional Information: Process control is maintaining, without deviation, established processes and procedures, and an escape is any irregularity in a process. Messages like this and others have been given at supplier seminars, and at individual supplier facilities on a continuing basis. Charts and videos depicting change/process controls have also been distributed among the supplier community.

Standard 8

Practice: Job Shadowing/Mentoring
Prime Contractor: Boeing Rocketdyne
Location: Canoga Park, California
Point of Contact: Alan Kay
Phone Number: 818-586-7566
E-mail: alan.r.kay@boeing.com

Overview: The Job Shadowing program allows co-workers to experience lateral employment scenarios. Practical knowledge is gained from company experts in a related field of interest. Actual "hands-on" participation coupled with classroom learning gives the participants both mentoring and theory.

Job/Shadowing/Mentoring opportunities related to Process Control can include:

- Non-Destructive Test & Inspection, Precision Measurement
- Quality Engineering
- Quality Planning
- Procurement/Supplier Management
- Manufacturing Engineering & SPC
- NC Machining
- Reliability & System Safety

Standard 8

Practice: Mentoring
Prime Contractor: Lockheed Martin Space Systems Company, Michoud Division
Location: New Orleans, Louisiana
Point of Contact: Shy Parikh or Ken Bornstedt
Phone Number: 504-257-1849 or 257-3642
E-mail: Shailesh.A.Parikh@maf.nasa.gov or Kenneth.A.Bornstedt@maf.nasa.gov

Overview: The structure of the program included 25 mentors with an equal number of protégé's, a program coordinator and an advisory board. Protégés and mentors are paired together by similar experience. The protégé is generally a person with high potential within their department and are recommended for participation by their management. The participation time is one year.

The benefits of the program are: good business, creates open discussion, helps in strategic and succession planning and is an excellent method for developing employees. It also develops a wider range of knowledge, increases development opportunities and is a training ground for future mentors. In addition, creates new ideas, personal development and satisfaction, and broader view of "life in the trenches".

Lessons Learned:

- Coordinator role is high maintenance role – but essential
- Create a structure but leave room for creativity
- Don't shorten the time – keep it one year
- Cross functional advisory board
- Respect the fact that this is a very personal relationship

Standard 8

Practice: Training Management System (Formal Training and Certification Programs, Skill Assessments)
Contractor: Hamilton Sundstrand Space Systems International, Inc.
Location: Windsor Locks, Connecticut
Point of Contact: Lionel Ribeiro
Phone Number: 860-654-3326
E-mail: lionel.ribeiro@hs.utc.com

Overview: The objective of a training management system is to ensure that employees have the required core competencies to perform their job effectively. Achievement of this objective can be accomplished using the following steps.

<u>Identify the jobs to be managed:</u>
Management must decide on the various job categories to be managed (e.g. Project Engineer, Inspector, Purchasing Agent). In some cases, these job categories may match the formal job description held by Human Resources. At other times, the job may have been tailored for a specific assignment and, although the education and general requirements may be the same as the formal job description, the specific tasks for the job may differ.

<u>Identify the tasks and skills needed to perform each job effectively:</u>
At a minimum, the major skills needed to perform a job effectively must be identified (e.g. writing specifications, dimensional inspection, writing purchase orders). In addition, for each of these major skills, multiple lower-level skills or knowledge may also be required (e.g. MS Word, geometric tolerancing, knowledge of FAR requirements). The culmination of this activity should be a skill assessment survey, which will provide a baseline of the skills needed for each job.

<u>Complete skill assessment survey:</u>
The ideal method for assessing the skill level, and as a result the training needed for each employee, is a one-on-one meeting between a supervisor and the employee where the skill assessment survey is reviewed and discussed. In this way, mutual agreement and understanding on where the skill gaps exist can be obtained.

<u>Establish a training and development plan:</u>
Employees learn their job in a variety of ways therefore a training and development plan should not be only limited to formal training classes. Other methods such as on-the-job training, computer-based training or being mentored by a more experienced worker can be equally if not more effective. It is important to recognize that repetition is often the road to mastery so plans should build in the opportunity for the employee to practice what is being learned. This is especially important where certification is required. Certifications offer objective evidence that a certain level of proficiency has been achieved through the use of testing (written and practical).

Finally, as gaps are closed they need to be documented providing the company with the assurance that an employee is prepared to effectively perform the job and the employee with a sense of accomplishment.